METHOD FOR FABRICATING A REDUCED-HEAVE FLOATING STRUCTURE

FIELD OF THE INVENTION

[0001] This invention relates to a method for installing a heave plate on a floating structure, for example a spar, and to floating structures so constructed. The method includes providing a heave plate and a floating structure at an offshore joining site and methodology for connecting the heave plate to the floating structure.

BACKGROUND

[0002] As the petroleum industry ventures to deep-water offshore locations to find sources of hydrocarbons, technology must be developed in order to retrieve these hydrocarbons. More and more, floating structures as opposed to bottom-founded structures are used in these deep-water applications. A particular floating structure used by the petroleum industry in deep water operations is the spar or deep-draft caisson vessel (DDCV), The spar or DDCV-type structure has a long vertically-disposed floating hull or caisson that, when in a floating operating position, has an upper portion above the water line that supports a drilling and/or production deck, and a lower portion below the ocean water line that provides buoyancy for the hull and deck. The spar or DDCV may be moored to the seafloor using mooring lines. Vertical pipes, known as risers, may be used to connect the subsea wells and the spar or DDCV to serve as conduits for the production of hydrocarbons and/or to provide access for drilling or workover activities.

[0003] The spar hull is typically cylindrical in shape, typically with a buoyant section at its upper end, a skirt-section at the middle, and a soft tank section at the lower end. The buoyant section is typically a hard tank, which provides the required buoyancy for the spar platform and can withstand hydrostatic pressure. The soft tank provides buoyancy for initial horizontal tow and subsequent upending. Once in place, both skirt section and soft tank can be filled with seawater. They are open to the sea

at the bottom of the hull. In some cases the soft tank might be ballasted with heavy materials such as ore or concrete for added stability.

[0004] The spar's deep draft hull, which typically will extend below the wave zone of the body of water, offers excellent global motion responses such as heave or vertical motions caused by offshore wave forces. Reduction of these motions provides several operational benefits including the ability to use top-tensioned risers with surface well-control trees for the wells used to produce the field, which provides the operator with more options for efficiency and reduced costs.

[0005] Because of the severity of some offshore environments, additional reduction of the heave, pitch and roll motions of the DDCV structure may be desired. Many solutions have been proposed, including the attachment of a horizontally disposed heave plate to the DDCV hull. For example, see US Patents 5,558,467 "Deep water offshore apparatus" and 5,722,797 "Floating caisson for offshore production and drilling". The heave plate provides added mass and damping to the floating structure by increasing the horizontal surface area at depths below the active wave actions that are located near the surface of the ocean.

[0006] However, there are logistical problems in implementing the heave plate concept. Because of convenience and cost efficiencies, offshore floating structures are almost always constructed on land and then transported to sea for installation. It is often cost-prohibitive and is logistically difficult to fabricate an offshore floating structure at sea. In regards to the heave plate configuration, constructing and combining the spar hull and the heave plate on land would provide similar efficiencies and costs savings. However, the reduced-heave configuration must still be transported to sea for installation. Because of the significant draft requirements caused by the heave plate configuration, transportation of the spar from an on-shore construction site to an offshore installation site is simply impractical.

[0007] Accordingly, what is needed is a method for providing a horizontally disposed heave plate on a floating structure, such as a DDCV or spar structure, which allows construction of the heave plate and the floating structure on land, while

providing for the attachment of the heave plate to the floating structure at or near the offshore installation site. The current invention satisfies this need.

[0008] For additional information, see U. S. Patent 3,101,798, Marine Drilling Apparatus; U. S. Patent 3,572,041, Spar-Type Floating Production Facility; U. S. Patent 3,921,557, Floating Storage Unit; U. S. Patent 4,606,673, Spar Buoy Construction Having Production and Oil Storage facilities and Method of Operation; U. S. Patent 4,702,321, Drilling, Production, and Oil Storage Caisson for Deep Water; Lowd, Judson D. and Hill, E. C., *Use of a Spar Buoy Designed for Interim Production Processing*; Offshore Technology Conference, OTC 1333, May 1971; U. S. Patent 5,558,467, Deepwater Offshore Apparatus; U. S. Patent 5,722,797, Floating Caisson for Offshore Production and Drilling; U. S. Patent 6,206,614, Floating Offshore Drilling/Producing Structure; Tanaka, K., et al.; *A Study on the Installation of a Submerged Caisson in Deep Waters*, Offshore Technology Conference, OTC 5606, May 1987; Walker, S. et al.; *STAPLA - The Design of a Variable Draught Semi-Submersible Floating Production Vessel,* Proceedings of the first European Offshore Mechanics Symposium, August 1990; U. S. Patent 5,609,442, Offshore Apparatus and Method for Oil Operations; U. S. Patent 5,924,822, Method for Deck Installation on an Offshore Substructure.

SUMMARY OF THE INVENTION

[0009] The invention includes a method for installing a heave plate on an offshore floating structure. The method includes providing a heave plate and a floating structure at an offshore joining site. The heave plate may contain a template capable of receiving the horizontal cross section of the floating structure. The method includes vertically positioning the floating structure with the heave plate along a common vertical axis. The method includes contacting the floating structure with the template of the heave plate and connecting the heave plate to the floating structure.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A shows a side view of a typical DDCV or spar structure.

Fig. 1B shows a plan view of the hull of the DDCV or spar structure of Fig. 1A.

Fig. 2A is a plan view of one embodiment of a heave plate that may be used in accordance with the invention.

Fig. 2B is a schematic view of Fig. 2A.

Fig. 3A is a side view of a floating structure and heave plate provided at an offshore joining site.

Fig. 3B is a schematic view showing the vertical positioning of the floating structure and heave plate in accordance with one embodiment of the invention.

Fig. 3C is a schematic view of one embodiment in which guide lines are used to control movement of a submerged heave plate.

Fig. 4 is a schematic view of one embodiment of the invention in which the heave plate is positioned below the lower end of the floating structure.

Fig. 5 is a schematic view of one embodiment of the invention in which connection of the heave plate to the floating structure is made by grouting the annulus therebetween.

Fig. 6A is a schematic view of an embodiment of a heave plate that can be used in accordance with the invention.

Fig. 6B. is a cross-sectional side view of the heave plate of Fig. 6A.

Fig. 7A is a side view showing an embodiment of a heave plate being provided to an offshore joining site.

Fig. 7B is a side view showing another embodiment of a heave plate being provided to an offshore joining site.

Fig. 8 is a side view showing an embodiment of a heave plate being provided to an offshore joining site, wherein the heave plate serves as a vessel for transporting the deck.

Fig. 9 is a side view showing vertical positioning of the heave plate and hull in accordance with an embodiment of this invention.

Fig. 10 is a side view showing an embodiment of the invention in which the heave plate is positioned above the upper end of the hull.

Figs. 11A-C are side views of an embodiment of the invention showing the positioning of the heave plate from the upper end of the hull to the lower end.

Fig. 12A is a plan view showing a heave plate that can be used in accordance with an embodiment of this invention.

Fig. 12B is a schematic view of the heave plate of Fig. 12A.

Figs. 13A-B are side views of a heave plate in the form of a split vessel that can be used in accordance with an embodiment of this invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] The present invention will be described in connection with its preferred embodiments. However, to the extent that the following description is specific to a particular embodiment or a particular use of the invention, this is intended to be illustrative only and is not to be construed as limiting the scope of the invention. On the contrary, it is intended to cover all alternatives, modifications, and equivalents that are included within the spirit and scope of the invention, as defined by the appended claims.

[0011] As used herein and in the claims the phrase "floating structure" is meant to refer to any structure that will float in a body of water. Floating structure refers to a structure that floats when in its final installed position, however, such a structure may also be capable of sinking in a water body, for example, by ballasting. Examples of floating structures, include, but are not limited to, offshore floating structures, spars, classic spars, deep-draft caisson vessels, truss spars, cell spars, pipe spars and other structures used in the offshore petroleum industry.

[0012] As used herein and in the claims the term "spar" is meant to refer to any spar-type floating structure, including but not limited to, classic spars, deep-draft caisson vessels, truss spars, cell spars and pipe spars.

[0013] As used herein and in the claims the phrase "heave plate" is meant to refer to any device which is suitable for attachment to a floating structure and is useful for

providing added mass and damping to the floating structure by increasing the horizontal surface area at depths below the active wave zones of a water body. A heave plate can be of any shape, for example, a relatively planar member in a rectangular, circular, polygonal, elliptical, or other regular or irregular shape. A heave plate may include a void area which may be used as a template and facilitate attachment to a floating structure.

[0014] As used herein and in the claims the term "template" is meant to refer to a cut out portion of a heave plate. The template may partially or completely pierce through the heave plate. In the alternative case where the template completely pierces through the heave plate a hole or void is created in the heave plate. In the alternative case where the template only partially pierces through the heave plate a well or depression is created in the heave plate. A template may also be designed to partially pierce some portion of the heave plate and completely pierce a portion of the heave plate to allow, for example, a moonpool opening in a heave plate that is attached to the bottom of a spar. The template may be designed to any shape and dimension to allow the heave plate to fit around a floating structure.

[0015] As used herein and in the claims the terms "hull" and "caisson" are used interchangeably to describe the underwater portion of a spar that provides buoyancy and stability.

[0016] In one alternative embodiment, the floating structure applicable for this invention is a DDCV or spar structure, for example as shown in Fig. 1A. By "floating" structure, it is meant that the structure floats when in its final installed position. The method of attaching a heave plate, as disclosed herein, can be used on any floating structure to reduce or dampen the vertical or heave motions acting upon the floating structure. In an alternative embodiment, the heave plate is installed on a DDCV or spar structure, which has a substantially rigid body 10 that is typically but not necessarily cylindrical, with an upper portion 20 above the surface of the ocean 30 supporting a deck 40, and a lower portion 50 below the surface of the ocean 30. The spar structure may be of different geometric designs, for example of a cylindrical, multi cylindrical, polygon, multiple polygon, oval, octagonal or decagonal shape.

Anchor lines 25 are used to secure or moor the floating structure to the seafloor. Fig 1B shows a plan view of the spar depicted in Fig 1A. This view shows the cross section 70 of the spar hull and the moonpool 71 extending through the spar. The moonpool may be sized to accommodate drilling equipment and production risers.

[0017] Referring now to Figs. 2A and 2B, the heave plate 100 has a large horizontal surface area that is considerably larger than the horizontal cross section 70 (as shown in Fig. 1B) of the floating structure 10. The particular dimensions of the heave plate 100 can be determined by one of ordinary skill in the art based upon the size of the floating structure and the environmental forces being addressed. The heave plate 100 is not limited to any particular shape, as it may be circular, square, rectangular, or any other shape. The heave plate 100 may contain a template 110 in the form of an opening having a cross-section capable of receiving the horizontal cross section 70 of the floating structure 10, as will be explained later. The term "horizontal" is used in relation to the floating structure in its final installed position, i.e., the horizontal cross section 70 is perpendicular to the longitudinal axis of a cylindrically shaped DDCV or spar floating structure, as indicated in Fig. 1B. Heave plates 100 can be attached at the bottom and/or mid level of the spar hull.

[0018] Figs. 3A and 3B illustrate an alternative embodiment of the invention. The floating structure 10 and the heave plate 100 are provided at an offshore joining site 5. The offshore joining site is preferentially, but does not have to be, near the final installation location of the floating structure i.e. the field or production location to minimize towing distances after the joining operation.

[0019] Referring to Fig. 3B, the heave plate 100 is lowered below the surface of the ocean 30 to a depth that would provide sufficient vertical clearance 130 between the heave plate 100 and the bottom of the floating structure 10 if the heave plate 100 and floating structure were in vertical alignment. Guide lines 160 (shown if Fig. 3C) attached to the heave plate 100 from a surface vessel 150 may be used to control the alignment and depth of the heave plate 100 in this lowering process. Next, as indicated in Fig. 4, the floating structure 10 may be positioned vertically (if not already in a vertical position) and aligned along a common vertical axis with the

heave plate 100 so that the template 110 is beneath the hull of the floating structure 10. The floating structure 10 may then be ballasted and lowered into the heave plate's template 110. Alternatively, guide lines 160 can be used to lift the heave plate template 110 to contact the floating structure 10. Latching devices 170 may be present on the floating structure 10 and/or heave plate 100, which may be activated upon joining of the two structures. Referring now to Fig. 5, once the heave plate 100 is positioned at the lower end of the floating structure 10, final connection can be achieved by grouting the annulus 180 between the template 110 and the floating structure 10. Alternatively, mechanical means may be used to make the final connection between the lower end of the floating structure and the heave plate.

[0020] After the heave plate 100 is structurally connected to the floating structure 10 the combined structure, i.e. the reduced-heave caisson vessel, can be towed, if necessary, to the field location and installed. Provision of the deck and installation of the facility at the field location can be accomplished using conventional techniques.

[0021] Referring now to Figs. 6A and 6B, one alternative template 110A for an embodiment defines an opening in the heave plate 100A capable of receiving the horizontal cross section 70 of the floating structure 10. The opening that defines the template 110A may alternatively extend only through a portion of the heave plate 100A. In other embodiments the template may alternatively contain an opening in the heave plate 100A which is capable of receiving the horizontal cross section 70 of the floating structure 10 through the entire heave plate 100A thickness. In the alternative where the template opening 110A extends only part way through the heave plate 100A, a portion of the surface area of the template opening 110A may alternatively extend through the entire heave plate and be sized to contain a moonpool-sized opening 111A for passage of drilling equipment and riser pipes. For example the moonpool sized opening 111A depicted in Figs. 6A and 6B may be sized to match the moonpool 71 depicted in Fig 1B.

[0022] Referring now to Fig. 7A, the heave plate 100 useful for embodiments of the invention can be constructed so that it will be buoyant and seaworthy, and may

alternatively be used as a vessel 100B which is capable of being transported on water. The heave plate/vessel 100B can incorporate an independent power and navigation system to get to the offshore joining site 5, but because the heave plate/vessel 100B may also be installed on the floating structure 10 as the heave plate 100, it is preferred that the vessel 100B be a simplified barge and transported to the joining site 5 using a second vessel. The vessel 100B may be constructed to have the capacity for variable buoyancy, for example, the vessel 100B may contain floodable chambers not shown or other means for adding ballast to submerge the vessel 100B beneath the surface of the ocean. Alternatively, the heave plate 100 can be constructed without buoyancy, such as a truss or girder stiffened plate 100C, as shown in Fig. 7B. This non-buoyant heave plate 100A may be transported to the installation site, for example on transportation barge 190C, or by other means.

[0023] Referring now to Fig. 8, another embodiment of the invention is shown where the heave plate 100D is first used as a vessel to transport the deck 40 to the joining site 5. After the weight of the deck 40 is transferred from the heave plate/vessel 100D to the floating structure 10, the heave plate/vessel 100D is positioned and attached at a desired point along the depth of the hull of the floating structure 10 for use as the heave plate.

[0024] To practice this embodiment of the invention, both the heave plate 100 and floating structure 10 are provided at the joining site 5. As shown in Fig. 8, the heave plate 100 is first used as a vessel 100D to transport the drilling and production deck 40, or topsides, to the joining site 5. The deck 40 and vessel 100D can be constructed and commissioned onshore using standard techniques, which can provide cost savings as opposed to commissioning the deck offshore.

[0025] Referring now to Fig. 9, the floating structure 10 may be provided at the joining site 5, positioned vertically if not already in a vertical position, and submerged beneath the surface of the ocean 30. The steps of vertically positioning and submerging the floating structure 10 can be accomplished using various known techniques. The depth to which the floating structure may be submerged is selected to provide sufficient vertical clearance 130D between the submerged floating

structure 10 and the heave plate/vessel 100D. The submerged structure 10 may rest on the sea floor, as indicated in Fig. 9, or it may be suspended at a selected depth. In this alternative embodiment sufficient vertical clearance 130D between the floating structure 10 and vessel 100D may therefore be provided. Referring to Fig. 10, the heave plate/vessel 100D may be vertically positioned above the submerged floating structure 10 so that the template 110D is substantially aligned over the submerged structure 10. Joining lines 250 may be used to contact the floating structure 10 and template 110D. After the floating structure 10 and deck 40 come in contact, the floating structure 10 may be deballasted and the weight of the deck 40 is transferred from the heave plate/vessel 100D to the floating structure 10. After this weight transfer, the buoyancy of the heave plate/vessel 100D is decreased, for example the vessel 100D is ballasted by flooding, and is lowered along the length of the hull to the lower end of the floating structure 10, as shown in Figs. 11a - 11c. The vessel 100D is then structurally connected at the bottom of the floating structure 10, or any other depth desired, and is used as the heave plate 100. For example, the heave plate 100D may be finally connected after reaching the location depicted in Fig. 11B.

[0026] After the heave plate 100D is structurally connected to the floating structure 10, the reduced-heave caisson vessel and deck can be towed to the field location, if necessary, and installed using conventional techniques.

[0027] . Referring now to Fig. 12A, the heave plate/vessel 100D may contain a template 110D, that defines an opening in the heave plate/vessel 100D capable of receiving the horizontal cross section 70 of the floating structure 10. As is evident, the opening that defines the template 110B for this embodiment extends through the height of the heave plate/vessel 100D, as is indicated in Fig. 12B.

[0028] If the floating structure 10 contains equipment or obstructions on the exterior of its hull that would impede the transfer of the heave plate/vessel 100D from the top to the lower end of the floating structure 10, for example fairleads or steel catenary riser porches, slots 120D in template 110D may be provided to allow an unimpeded transfer of the heave plate 100D, as shown in Figs. 12A and 12B.

[0029] Referring now to Figs. 13A and 13B, the heave plate/vessel useful for this embodiment may comprise a split vessel 100E, comprising an upper portion 200 and a lower portion 210. The split vessel 100E may be used as a seaworthy vessel to transport the drilling and production deck 40 to the joining site 5. The upper portion 200 of the split vessel 100E may remain at the upper end of the floating structure 10 as a deck structure, while the lower portion 210 of the split vessel 100E may be lowered or raised along the length of the floating structure 10 to be used as the heave plate.

[0030] Another potential benefit for providing a heave plate on a DDCV or spar structure is that the hull of the vessel may be designed and ultimately constructed smaller in size, thus providing cost savings in its construction. Generally, the hull of the vessel must be of a sufficient size to provide adequate buoyancy for the weight of the deck and hull, and be a sufficient length to minimize heave motions. The limiting factor for reducing the length of the hull may be heave motions. In other words, reducing the hull length may cause unacceptably large heave motions before it will cause buoyancy problems. By adding a horizontally disposed heave plate to decrease these motions, one may construct a DDCV or spar structure that is shorter in length, and obtain the corresponding cost savings while at the same time maintaining sufficient buoyancy.

[0031] The methodologies described herein may be used to construct offshore floating structures for use in exploring for and producing offshore hydrocarbon resources. The offshore floating structure may be for example a classic spar (e.g. a deep draft caisson vessel ("DDCV") or a truss spar) that is equipped with a deck or a production or export riser. In the case of the spar, the deck can support offshore hydrocarbon resource (i.e. oil and gas) exploration, drilling and production operations. The deck may be use to conduct offshore seismic data collection. Alternatively, the deck can support offshore drilling equipment for oil and/or gas drilling operations. The deck may also support oil and/or gas production equipment for the production of oil and gas natural resources. Produced oil and/or gas may then be offloaded from the deck by, for example, pipeline to shore or a transport ship or barge and then moved to

shore. The oil and gas may then be refined into usable petroleum products such as, for example, natural gas, liquefied petroleum gas, gasoline, jet fuel, diesel fuel, heating oil or other petroleum products.

[0032] The present invention has been described in connection with its preferred embodiments. However, to the extent that the foregoing description was specific to a particular embodiment or a particular use of the invention, this was intended to be illustrative only and is not to be construed as limiting the scope of the invention. On the contrary, it was intended to cover all alternatives, modifications, and equivalents that are included within the spirit and scope of the invention, as defined by the appended claims.

[0033] All documents cited herein are fully incorporated by reference for all jurisdictions in which such incorporation is permitted and to the extent they are not inconsistent with this specification. Although some dependent claims have single dependencies in accordance with U.S. practice, each of the features in any of the dependent claims can be combined with each of the features of one or more of the other dependent claims dependent upon the same independent claim or claims. Certain features of the present invention are described in terms of a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges formed by any combination of these limits are within the scope of the invention unless otherwise indicated.